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WDM LAYER-BASED OCHP DEVICE AND METHOD THEREOF

## FIELD OF THE INVENTION

[0001] The present invention relates to a WDM layer-based Optical Channel Protection (OChP) device and method thereof.

## 5 BACKGROUND OF THE INVENTION

[0002] As Dense Wavelength Division Multiplex (DWDM) technology evolves rapidly, the transmission rate of WDM system increases quickly to meet ever-growing network data service and voice/image service requirements as well as telecom operators' ever-increasing demand for higher transmission bandwidth; at the same time, the reliability of WDM system becomes a prominent issue. On the basis of enhanced reliability of system modules, implementing a good protection solution will bring significant benefit to system reliability.

[0003] Presently, there are two types of WDM system protection solutions: one is Optical Multiplex Segment Protection (OMSP), which is also referred to as optical line protection; the other is OChP; the object of the former is primarily to protect transmission optical fibers; while the latter provides equipment-level protection and it employs the following working principle: whenever the signal transmission in a channel is interrupted or the performance is degraded to a certain degree, the switching device of the system will switch the signals from the channel to a

protection channel to transmit; whether to perform the switch is solely determined by the determination device in the receiver according to the quality of received signals and requires no additional detection device.

[0004] As DWDM technology evolves by leaps and bounds and the transmission rate 5 increases in doubles, the traffic in each channel becomes increasingly heavier, and the role of transmission channels in the network becomes more significant; as a result, the security and reliability of each channel becomes an inevitable factor in the network, which requires better OChP solutions.

[0005] One of the common OChP solutions for traditional WDM systems employs 1+1 or 10 1:1 scheme (where 1+1 represents cold backup; 1:1 represents hot backup; the difference between them lies in whether the protection channel transfers traffic when the working channel operates normally), i.e., a power distribution device is added at the optical signal input end of each working Optical Transform Unit (OTU), and one of the two signal outputs of the power distribution device is connected to the working OTU, the other signal output is connected to a backup OTU; in this 15 way, in case the working OTU fails, the input signals may be changed to the backup OTU so as to ensure normal operation of the system. A typical 1+1 solution is shown in Fig.1. And the coupler shown in Fig.1 may be substituted with a 1×2 optical switch. The solid line portion in Fig.1 shows routes of working channels, and the dotted line portion shows routes of protection channels. The feature of such a protection solution is that it utilizes a wavelength signal to protect another

wavelength signal; therefore the number of working channels is equal to that of protection channels. Though above WDM-based 1+1 OChP solution can solve the problem of channel reliability, it requires higher initial cost of equipment because half of the wavelength resource is wasted.

## 5 SUMMARY OF THE INVENTION

[0006] The object of the present invention is to solve the above problem and to provide a WDM layer-based OChP device and method thereof, so as to realize an independent protection mechanism for the WDM layer with reduced wavelength waste and initial cost of equipment.

[0007] To attain said object, the present invention provides a WDM layer-based OChP device and a method thereof, so as to achieve signal transmission for working channels and routing selection for protection channels between the traffic transferred and the WDM system.

[0008] Said OChP device comprises a transmitting module and a receiving module; said transmitting module and receiving module both comprise N working channels connected to the receiving ends and transmitting ends of N working channels in the WDM system respectively, wherein said transmitting module and receiving module also comprise M protection channels, which are connected to the receiving ends and transmitting ends of M protection channels in the WDM system, and a switching device, which is designed to switch the signals in specified working channels to specified protection channels or switch the signals in specified protection channels back

to specified working channels according to the switching requests from the WDM system; wherein M and N are both natural numbers, and M<N.

[0009] Said OChP method comprises the following steps:

- (1) The WDM system monitoring the quality of signals in each channel and routing state of OChP modules in the system in real time;
- (2) The WDM system determining whether there are some signals in the working channels should be switched to the protection channels; if yes, the WDM system selecting the protection channels;
- (3) The WDM system sending accurate switching requests to the OChP transmitting module and the OChP receiving module;
- (4) The OChP transmitting module and the OChP receiving module performing switch according to said switching requests from the WDM system.

[0010] With above solution, in normal cases, the OChP module chooses corresponding working channels for N-way signals entering said OChP module to access the WDM system to transmit; at the receiving end, the OChP module similarly chooses working channels to receive the signals; at this time, no traffic is transmitted in the protection channels, or the traffic transmitted through the protection channels will not be received by the OChP receiving module (only the traffic

with low priority is transmitted). In case the quality of signals in  $m$  channels ( $1 \leq m \leq M$ ) is degraded or lost due to channel failure, the OChP module at the transmitting end will switch the signals to protection channels to transmit; while the rest  $N-m$  signals are transmitted through the working channels; at the receiving end, the OChP module chooses corresponding protection channels to receive said  $m$  signals, and the rest  $N-m$  signals are received by the working channels. In this way, a WDM layer-based M:N OChP solution is implemented. Due to the fact that the number of channels and the probability of degraded signals or lost signals are trivial, the number  $M$  of protection channels may be less than the number  $N$  of working channels. Compared with 1+1 protection solution, it helps to save resource and initial cost. In case the number  $M$  of protection channels is more than 1, there are two or more cascade backup OTUs, which further reduces the risk of ruined backup performance due to failures of backup OTUs or failures of two or more working OTUs, without increasing construction cost of the system.

#### BRIEF DESCRIPTION OF THE DRAWINGS

[0011] Fig. 1 is a schematic diagram of a traditional WDM-based 1+1 OChP solution.

15 [0012] Fig. 2a shows the positions of the OChP modules in the WDM system according to the present invention.

[0013] Fig. 2b is a schematic diagram of a WDM-based 1+N OChP solution according to the present invention.

[0014] Fig. 3 shows the internal structure of an OChP module composed of couplers and optical switches.

[0015] Fig. 4 shows the internal structure of the OChP module composed of optical switches.

[0016] Fig. 5 shows the structure of an OChP module composed of  $N \times (N+M)$  optical switches.

## DETAILED DESCRIPTION OF THE EMBODIMENTS

[0017] The present invention will be described in further detail with reference to the following embodiments and drawings. The embodiments are suitable for both hot backup (M:N) and cold backup (M+N).

10 [0018] Referring to Fig. 2a, the WDM layer-based OChP device according to the present invention comprises a transmitting module and a receiving module; said transmitting module and receiving module both comprise N working channels (N inputs and N outputs) connected to the receiving ends and transmitting ends of N working channels in the WDM system respectively.

15 [0019] Said transmitting module and receiving module also comprise M protection channels connected to the receiving ends and transmitting ends of M protection channels in the WDM system respectively.

[0020] Said transmitting module and receiving module also comprise a switching device, which is designed to switch the signals in specified working channels to specified protection channels or switch the signals in specified protection channels back to specified working channels according to the switching requests from the WDM system; wherein M and N are both natural numbers, and  $M < N$ . Referring to Fig. 2b (when  $M=1$ ), compared with 1+1 protection solution, it helps to save resource and initial cost by using only one protection channel to protect the working channels.

[0021] Though the 1:N or 1+1 protection solution shown in Fig. 2b can help to reduce the number of backup OTUs in use and enhance utilization ratio of optical wavelength, the premise for it is that the OTUs should operate normally; and if a backup OTU goes into a “trouble” state or OTUs in two or more working channels protected by the same backup OTU goes into a “trouble” state, the backup performance of the system is ruined. The solution is to have more than one protection channels, as shown in Fig. 3, Fig. 4, and Fig. 5.

[0022] Said device works as follows: in normal cases, the OChP module chooses corresponding working channels for N-way signals entering said OChP module to access the WDM system to transmit; at the receiving end, the OChP module similarly chooses working channels to receive the signals; at this time, no traffic is transmitted in the protection channels, or the traffic transmitted through the protection channels will not be received by the OChP receiving module. In case the quality of signals in m channels ( $1 \leq m \leq M$ ) is degraded or lost due to channel failure, the

OChP transmitting module switches the signals to protection channels to transmit; while the rest N-m signals are transmitted through the working channels; at the receiving end, the OChP module chooses corresponding protection channels to receive said m signals, and the rest N-m signals are received by the working channels. If a working channel for a signal currently transmitted through

5 the protection channel recovers, the OChP module switches the signal back to the working channel.

[0023] Here, whether the signal in a working channel is switched to a protection channel is

determined by the performance of the working channel and is solely determined by the

corresponding receiver in the WDM system without any additional detection device because all

receivers in the WDM system possess the function. In addition, whether the signals transmitted

10 through a protection channel are switched back to the working channel also is determined by the

performance of the working channel; therefore, the protection solution is WDM layer-based.

[0024] Both for working channels and protection channels, the OChP modules only choose

corresponding routes for the signals instead of performing any treatment to the traffic carried by the

signals; therefore, the OChP modules are transparent to the traffic.

15 [0025] Because the selection of routes of the signals performed by OChP modules is based on

the performance of channels in the WDM system, it requires support from an appropriate protocol

between the WDM system and the OChP modules. The protocol shall support the following

functions:

- (1) The WDM system monitoring the quality of signals in each channel and routing state of OChP modules in the system in real time;
- 5 (2) The WDM system determining whether some signals in the working channels should be switched to the protection channels and selecting the protection channels; similarly, the WDM system determining whether there are some signals in the protection channels should be switched back to the working channels;
- (3) The WDM system sending accurate switching requests to the OChP transmitting module and the OChP receiving module simultaneously;
- 10 (4) The OChP modules performing switching according to said switching requests from the WDM system.

[0026] In view of above required features of OChP modules, we implemented the design. And the typical embodiments are described as follows:

[0027] Embodiment 1.

[0028] The OChP modules comprise 50:50 couplers (also referred to as shunts) and M:N (or 15 M×N or N×M, indicating M or N input ports and N or M output ports) optical switches; Referring to Fig. 3, the switching device of the transmitting module comprises N 50:50 couplers and an N×M optical switch; one of the two output ports of each coupler is connected to a working channel, and

the other is connected to an input port of the  $N \times M$  optical switch;  $M$  output ports of the  $N \times M$  optical switch are connected to the  $M$  protection channels in the WDM system respectively; the switching device of the receiving module comprises 50:50 couplers and an  $M \times N$  optical switch, one of the two input ports of each coupler is connected to a working channel in the WDM system, and the other is connected to an output port of the  $N \times M$  optical switch;  $M$  input ports of the  $M \times N$  optical switch are connected to the  $M$  protection channels in the WDM system respectively.

5 [0029] In the above case, the  $M:N$  optical switch should be controlled so that the lasers for working channels and protection channels at receiving end of the WDM system are not open simultaneously; instead, only either of them can be in working state; however, no such requirement  
10 is necessary for the lasers at transmitting end.

[0030] Embodiment 2.

[0031] The OChP modules comprise  $1 \times 2$  optical switches and  $M:N$  optical switches. Referring to Fig. 4, the switching device of the transmitting module comprises  $N 1 \times 2$  optical switches and an  $N \times M$  optical switch; one of the two output ports of each  $1 \times 2$  optical switch is connected to a working channel in the WDM system, the other is connected to an input port of the  
15  $N \times M$  optical switch; and  $M$  output ports of the  $N \times M$  optical switch are connected to  $M$  protection channels in the WDM system respectively. The switching device of the receiving module comprises  $N 1 \times 2$  optical switches and a  $M \times N$  optical switch; one of the two input ports of each  $1 \times 2$  optical

switch is connected to a working channel in the WDM system, the other is connected to an output port of the  $N \times M$  optical switch; and  $M$  input ports of the  $M \times N$  optical switch are connected to  $M$  protection channels in the WDM system respectively.

[0032] The above solution requires strict protocol control for the  $M:N$  optical switch and the 5  $1 \times 2$  optical switches, i.e., the optical switches at both ends shall be switched to corresponding routes simultaneously; however, no such requirement is necessary for the lasers at transmitting end and receiving end.

[0033] Embodiment 3.

[0034] The OChP modules comprise  $N \times (N+M)$  optical switches. Referring to Fig. 5, the 10 switching device of the transmitting module comprises an  $N \times (N+M)$  optical switch, the  $N+M$  output ports of which are connected to  $N$  working channels and  $M$  protection channels in the WDM system respectively; the switching device of the receiving module comprises a  $(N+M) \times N$  optical switch, the  $N+M$  input ports of which are connected to  $N$  working channels and  $M$  protection channels in the WDM system.

15 [0035] The above solution requires that the optical switches at both ends be switched to corresponding routes simultaneously; however, no such requirement is necessary for the lasers at transmitting end and receiving end.

[0036] The following calculation shows that the reliability of the system can be enhanced when  $M>1$ .

[0037] For any of above embodiments, for 2+16 wavelength protection (equivalent to two cascaded OTUs, i.e., two independent 1+8 protection devices are cascaded to form a 2+16

5 protection device), according to the calculation, the Mean Time Between Failures (MTBF) is

prolonged by  $k/30$  times (compared with original solution of two independent 1+8 protection devices), where  $k$  is the ratio of system available time to Time Between Failures (TBF). For

example, if the availability of a single board is 99.99%, the value of  $k$  is about  $10^4$ ; whenever a 9 is

added after the decimal fraction part of the value of the availability, the value of  $k$  grows by an

10 order of magnitude. If  $M+N$  solution (i.e.,  $M$  cascaded OTUs) is used, the MTBF is prolonged by

$k^{M-1}P_8^2/P_{8M}^{M+1}$  times ( $P$  represents factorial function). It is obvious that the OChP method according

to the present invention helps to reduce cost and enhance system reliability when  $M>1$ .